CIRCULAR No. 444 NOVEMBER 1937
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

YIELD AND QUALITY OF SUGAR BEETS FROM VARIOUS ROTATIONS AT THE SCOTTS BLUFF (NEBR.) FIELD STATION, 1930–35

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INTRODUCTION

The acre yield of sugar in some of the sugar-beet-growing areas of the United States has been materially increased during the last two decades. This has been accomplished largely as a result of improved cultural practices, including crop rotation, increased use of manures and commercial fertilizers, disease control, choice of variety to be grown, and improved irrigation practice. In some cases the increase in yield of sugar per acre has been the result of increase in tonnages of sugar beets produced per acre, more or less at the expense of quality as expressed by sucrose percentage and the apparent purity coefficient of the beets. Factories in a number of districts have adopted a system of purchasing sugar beets on a price scale based on percentage of sucrose in the delivered crop. It follows that the higher the average sucrose test, the beet tonnage being generally maintained, the greater the net return per ton of beets delivered. Therefore consideration of cropping and manurial practices influencing quality is of practical importance.

The purpose of this circular is to present the results obtained over a period of 6 years, 1930–35, in a series of 29 crop rotations in which sugar beets were included.

[1] In cooperation with the Division of Western Irrigation Agriculture, Bureau of Plant Industry. The sugar-beet crops dealt with in this circular have been grown at the Scotts Bluff Field Station of the Division of Western Irrigation Agriculture at Mitchell, Nebr. The data on plot yields and the samples for chemical analysis have been supplied by that division. During these investigations special assistance was given by the late James A. Holden, formerly superintendent, and by the present acting superintendent, Lionel Harris. Acknowledgment is made to S. H. Hastings, principal agronomist, Division of Western Irrigation Agriculture, and to G. H. Coons, principal pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, for suggestions regarding the manuscript.

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ROTATIONS

The rotations from which data were taken are those maintained at the Scotts Bluff Field Station, Mitchell, Nebr. (table 1). This station is located in the North Platte reclamation project. Hastings,[2] in a general report on the crop rotations of this station, states that the soil where these investigations are conducted has been classed as Tripp very fine sandy loam, typical of the extensive areas of terraces lying north of the North Platte River, and that soils of this type are among the more productive found on the project. On the basis of the soil survey of Scotts Bluff County,[3] Hastings notes that the chief soils of the project range from a sandy loam to a loamy fine sand, with the Mitchell, a very fine sandy loam, predominating. Aside from the lowlands bordering the North Platte River, the agricultural lands have natural and effective drainage.

The station was established in 1910, and many of the rotations began in 1912; others were added in 1920 and 1926. The periods involved should be adequate to insure a stabilization of soil behavior for the various conditions imposed. The details of the lay-out of plots and methods of handling have been given in publications by Scofield and Holden [4] and Hastings.[5] In any 1 year each rotation was represented by one plot 165 by 82½ feet. The repetition of the rotations over a number of years is relied upon for reduction of chance occurrence and the assumption is made that soil-variability effects are minor or are largely compensated.

The sugar-beet nematode was not present in these plots in spite of repeated croppings or the short intervals between sugar-beet crops in certain of the rotations; however, the root knot nematode has been found on some plots.

The methods employed with the various crops conformed to the general practices of the area; sugar beets were planted during the latter part of April, 20 pounds of seed being used per acre, in rows 20 inches apart. Thinning and other cultural operations were performed according to standard methods and were uniform for the plots. The crop was harvested in late October and all the beets were weighed in determining the yields.

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[2] HASTINGS, S. H. IRRIGATED CROP ROTATIONS IN WESTERN NEBRASKA, 1912–34. U. S. Dept. Agr. Tech. Bull. 512, 36 pp., illus. 1936.

[3] SKINNER, L. T., and BECK, M. W. SOIL SURVEY OF SCOTTS BLUFF COUNTY, NEBRASKA. U. S. Dept. Agr. Bur. Soils Field Oper. 1913, Rept. 15; 2059–2097, illus. 1915.

[4] SCOFIELD, C. S. IRRIGATED CROP ROTATIONS IN WESTERN NEBRASKA. U. S. Dept. Agr. Tech. Bull. 2, 26 pp., illus. 1927.

[5] HASTINGS, S. H. EFFECT OF ALFALFA AND FARM MANURE ON YIELDS OF IRRIGATED CROPS IN THE GREAT PLAINS. U. S. Dept. Agr. Tech. Bull. 483, 40 pp. 1935.

TABLE 1.—*Crop rotations in which sugar beets were grown, Scotts Bluff Field Station, Mitchell, Nebr.*

Rotation no.	Year started	Years in rotation	Cropping system
		Number	
2	1912		Sugar beets, continuous.
18	1912	2	Sugar beets; spring wheat.
20	1912	2	Sugar beets; potatoes.
21	1912	2	Sugar beets; potatoes (manured).
22	1912	2	Sugar beets; oats.
23	1912	2	Sugar beets (manured); oats.
30	1912	3	Sugar beets, potatoes, oats.
31	1912	3	Sugar beets (manured), potatoes, oats.
32	1912	3	Sugar beets, corn, oats.
13	1926	2	Oats with sweetclover (green manure, fall-plowed); sugar beets second year.
15	1926	2	Same as 13 except that sweetclover was pastured with sheep before fall plowing; sugar beets second year.
19	1926	2	Same as 13 except that hay was removed in fall before plowing; sugar beets second year.
33	1926	3	Sugar beets, oats, and sweetclover (spring-plowed, green manure), potatoes.
43	1926	4	Oats seeded with sweetclover (pastured with sheep fall and spring), potatoes; third year oats and sweetclover (pastured with sheep, fall-plowed); fourth year sugar beets.
46–1	1926	4	Potatoes, sugar beets, oats, sugar beets. First crop of sugar beets.
46–2	1926	4	Second crop of sugar beets in the above rotation.
45–1	1920	4	Sugar beets (2 years), oats and sweetclover (pastured with sheep). First crop of sugar beets.
45–2	1920	4	Second crop of sugar beets in the above rotation.
47	1926	4	Oats seeded with sweetclover (spring-plowed June 1), potatoes, oats seeded with sweetclover (fall-plowed), fourth year sugar beets.
49	1926	4	Oats seeded with sweetclover (spring-plowed June 1), potatoes, third year sugar beets, fourth year beans.
41	1926	4	Sugar beets, oats, and sweetclover (fall-pastured with sheep), sweetclover (pastured with sheep and fall-plowed), potatoes.
40	1912	4	Sugar beets, alfalfa (2 years), potatoes.
42	1912	4	Sugar beets, alfalfa (2 years), oats.
60	1912	6	Sugar beets, alfalfa (3 years), potatoes, oats.
61	1912	6	Sugar beets (manured), alfalfa (3 years), potatoes, oats.
62	1912	6	Sugar beets, alfalfa (3 years), corn, oats.
64	1920	6	Sugar beets, oats, alfalfa (3 years), potatoes.
71–1	1920	7	Sugar beets, sugar beets (manured), oats, alfalfa (3 years), potatoes. First crop of sugar beets.
71–2	1920	7	Second crop of sugar beets (manured).

To determine sucrose percentages and apparent purity coefficients the plots were sampled, only normally competitive beets being taken. The numbers of beets comprising the samples ranged from 10 to 20. Sucrose was determined by the Sachs-Le Docte method. Apparent purity coefficients were computed from refractometer readings of total solids, except in 1930 and 1931, when the Brix spindle was used to determine total solids.

The results obtained are given as averages for the 6-year period beginning with 1930 (tables 2 and 3). The analysis-of-variance method has been applied to the data for the 29 rotations over the 6 years of the test (tables 4 and 5) the years of the test being used as the replications and the different crop rotations as the treatments. Variance not thus assignable has been used to compute experimental error. The values indicated as required for significance conform to the conventional requirement of two times the standard error of the difference. Because of the nature of the rotation plan and the limited statistical evaluation that may be applied, only the strongly contrasting items are stressed. As the rotations are continued and more annual records accumulate, consistency in performance over many years should permit more detailed conclusions and eliminate certain apparent contradictions.

TABLE 2.—*Sugar-beet crops in the various rotations at the Scotts Bluff Field Station, Mitchell, Nebr.*

[Data given as 6-year averages; yields calculated to acre basis]

Rotation	Years	Cropping system	Acre yield	Sucrose	Apparent purity coefficient	Sugar per acre	
						Gross	Indicated available
Continuous cropping:			*Tons*	*Percent*		*Pounds*	*Pounds*
No. 2		Sugar beets	5.2	18.3	93.2	1,904	1,774
Short rotations involving only cash crops:							
No. 18	2	Sugar beets; spring wheat	7.6	18.0	93.5	2,757	2,571
No. 20	2	Sugar beets; potatoes	7.6	17.7	92.6	2,702	2,496
No. 22	2	Sugar beets; oats	7.4	17.6	92.8	2,585	2,388
No. 30	3	Sugar beets, potatoes, oats	7.4	18.1	93.3	2,679	2,492
No. 32	3	Sugar beets, corn, oats	7.8	18.2	93.1	2,828	2,624
Average			7.6	17.9	93.1	2,710	2,514
Short rotations with soil-building legume crop:							
No. 13	2	Oats with sweetclover (green manure fall-plowed); sugar beets second year.	12.2	17.2	90.4	4,122	3,723
No. 15	2	Same as 13 except that sweetclover was pastured with sheep before fall-plowing; sugar beets second year.	13.9	16.7	90.1	4,650	4,182
No. 19	2	Same as 13 except that hay was removed in fall before plowing; sugar beets second year.	11.1	17.6	91.9	3,914	3,598
No. 33	3	Sugar beets, oats, and sweetclover (spring-plowed, green manure), potatoes.	15.4	17.5	90.9	5,295	4,802
Average			13.2	17.3	90.8	4,495	4,076
4-year rotations without soil-building legume crop:							
No. 46–1	4	Potatoes, sugar beets, oats, sugar beets. First crop of sugar beets.	10.1	17.9	91.5	3,635	3,323
No. 46–2	4	Second crop of sugar beets in the above rotation.	9.9	17.9	91.7	3,449	3,148
Average			10.0	17.9	91.6	3,542	3,236
4-year rotations with soil-building legume crop: [1]							
No. 43	4	Oats seeded with sweetclover (pastured with sheep fall and spring), potatoes; third year oats and sweetclover (pastured with sheep, fall-plowed); fourth year, sugar beets.	13.2	16.1	89.9	4,216	3,785
No. 45–1	4	Sugar beets (2 years); oats and sweetclover (pastured with sheep). First crop of sugar beets.	16.8	16.5	89.6	5,532	4,953
No. 45–2	4	Second crop of sugar beets in the above rotation.	13.7	17.4	91.5	4,750	4,350
No. 47	4	Oats seeded with sweetclover (spring-plowed June 1), potatoes, oats seeded with sweetclover (fall-plowed); fourth year, sugar beets.	13.7	17.0	90.8	4,667	4,226
No. 49	4	Oats seeded with sweetclover (spring-plowed June 1), potatoes; third year, sugar beets; fourth year, beans.	12.8	15.7	88.5	3,993	3,527
No. 41	4	Sugar beets, oats, and sweetclover (fall-pastured with sheep), sweetclover (pastured with sheep and fall-plowed), potatoes.	15.3	16.9	90.0	5,115	4,593
No. 40	4	Sugar beets, alfalfa (2 years), potatoes.	14.2	16.1	90.6	4,574	4,137
No. 42	4	Sugar beets, alfalfa (2 years), oats	14.0	16.6	91.2	4,680	4,224
Average			14.2	16.5	90.3	4,691	4,224

[1] Sweetclover or alfalfa spring-plowed preceding the crop except where indicated as fall-plowed.

TABLE 2.—*Sugar-beet crops in the various rotations at the Scotts Bluff Field Station, Mitchell, Nebr.*—Continued

Rotation	Years	Cropping system	Acre yield	Sucrose	Apparent purity coefficient	Sugar per acre	
						Gross	Indicated available
			Tons	*Percent*		*Pounds*	*Pounds*
Longer rotations (soil-building legume crop included):							
No. 60	6	Sugar beets, alfalfa (3 years), potatoes, oats.	12.5	16.1	90.3	4,051	3,655
No. 62	6	Sugar beets, alfalfa (3 years), corn, oats.	13.3	16.5	90.6	4,372	3,950
No. 64	6	Sugar beets, oats, alfalfa (3 years), potatoes.	14.9	15.2	88.7	4,541	4,027
No. 71–1	7	Sugar beets, sugar beets (manured), oats, alfalfa (3 years), potatoes. First crop of sugar beets.	13.4	15.2	88.5	4,039	3,568
Average			13.5	15.8	89.5	4,251	3,800
Difference required for significance.			2.12	1.02	1.78	781	724

TABLE 3.—*Comparison of rotations including sugar beets with and without manure applications, at the Scotts Bluff Field Station, Mitchell, Nebr.*

[Data given as 6-year averages; yields calculated to acre basis]

Rotation	Years	Cropping system	Acre yield	Sucrose	Apparent purity coefficient	Sugar per acre	
						Gross	Indicated available
			Tons	*Percent*		*Pounds*	*Pounds*
20	2	Sugar beets, potatoes	7.6	17.7	92.6	2,702	2,496
21	2	Sugar beets, potatoes (manured)	15.8	17.0	91.3	5,343	4,861
22	2	Sugar beets, oats	7.4	17.6	92.8	2,585	2,388
23	2	Sugar beets (manured), oats	17.3	16.4	89.2	5,640	5,027
30	3	Sugar beets, potatoes, oats	7.4	18.1	93.3	2,679	2,492
31	3	Sugar beets (manured), potatoes, oats.	16.6	17.5	91.2	5,792	5,277
60	6	Sugar beets, alfalfa (3 years), potatoes, oats.	12.5	16.1	90.3	4,051	3,655
61	6	Sugar beets (manured), alfalfa (3 years), potatoes, oats.	16.2	15.8	89.3	5,091	4,542
71–1 [1]	7	Sugar beets, sugar beets (manured), oats, alfalfa (3 years), potatoes.	13.4	15.2	88.5	4,039	3,568
71–2 [2]	7	Sugar beets (manured), oats, alfalfa (3 years), potatoes, sugar beets.	16.8	15.3	88.4	5,062	4,470
Average, with manure.			16.5	16.4	89.9	5,386	4,835
Average, without manure.			9.7	16.9	91.5	3,211	2,920

[1] First sugar-beet crop.
[2] Second sugar-beet crop.

TABLE 4.—*Data on stand, acre yield of roots, and sucrose percentage, 1930–35, Scotts Bluff Field Station, Mitchell, Nebr.*

Rotation no.	Stand [1]							Acre yield of roots							Sucrose						
	1930	1931	1932	1933	1934	1935	Mean	1930	1931	1932	1933	1934	1935	Mean	1930	1931	1932	1933	1934	1935	Mean
								Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
2	48	76	66	39	30	60	53	6.8	4.5	6.4	4.1	2.7	6.7	5.2	17.6	18.5	16.7	18.6	17.9	20.4	18.3
18	50	61	68	39	42	67	55	9.2	7.1	7.8	8.0	4.3	9.4	7.6	18.0	17.8	16.9	17.3	18.5	19.7	18.0
20	58	77	68	78	41	80	67	8.9	7.2	9.0	6.4	4.1	10.0	7.6	16.6	18.6	15.8	16.7	17.5	20.8	17.7
21	93	89	81	85	68	83	83	18.3	14.8	15.9	15.8	11.1	18.8	15.8	16.7	17.1	15.7	16.7	18.5	17.3	17.0
22	64	65	63	42	29	54	53	11.6	5.0	7.1	8.3	4.1	8.0	7.4	17.4	16.9	16.3	17.1	17.8	19.8	17.6
23	83	78	58	74	58	84	73	21.4	17.5	15.6	17.7	13.0	18.7	17.3	14.5	16.5	15.3	15.3	17.7	18.9	16.4
30	55	73	76	47	44	83	63	9.5	5.5	8.4	7.2	5.1	8.5	7.4	18.8	17.4	16.9	18.1	17.6	19.7	18.1
31	83	78	70	70	49	88	73	18.4	16.1	19.5	17.7	12.1	16.0	16.6	17.9	16.9	16.4	15.9	17.5	20.2	17.5
32	64	74	70	73	48	82	69	10.6	6.8	8.5	6.2	5.9	8.5	7.8	18.4	17.8	16.9	17.8	18.5	19.9	18.2
13	48	54	53	40	47	68	52	17.0	12.2	12.0	11.6	8.8	11.3	12.2	16.2	17.4	13.5	17.0	19.4	19.5	17.2
15	64	65	55	65	48	79	63	19.9	14.0	11.4	16.2	8.8	13.2	13.9	16.5	16.9	13.4	16.8	17.7	18.9	16.7
19	52	60	68	48	47	81	59	16.5	11.0	8.6	12.1	7.0	11.5	11.1	17.5	17.8	14.0	17.0	19.4	19.8	17.6
33	79	68	82	61	49	82	70	19.7	14.5	20.4	15.9	9.1	12.5	15.4	16.6	18.7	15.5	17.5	17.4	19.0	17.5
43	67	71	78	65	46	85	69	19.0	13.5	11.4	14.2	9.6	11.6	13.2	14.7	16.3	13.3	16.8	16.5	18.7	16.1
46–1	60	34	68	37	37	83	53	17.8	8.7	10.8	8.6	5.1	9.8	10.1	17.2	18.1	16.4	17.6	18.7	19.4	17.9
46–2	69	35	88	49	36	73	58	14.4	6.6	13.0	12.8	4.7	8.1	9.9	17.5	18.3	16.0	17.4	18.8	19.1	17.9
45–1	84	77	77	74	62	92	78	20.1	17.0	17.5	16.8	12.1	17.5	16.8	15.7	17.8	14.1	15.5	17.1	18.7	16.5
45–2	84	85	63	77	52	84	74	16.2	14.1	14.1	14.7	8.7	14.1	13.7	17.0	18.1	15.8	16.2	16.4	20.6	17.4
47	67	59	65	42	39	90	60	20.7	13.8	11.9	13.8	9.2	13.0	13.7	16.5	17.6	16.1	16.8	16.5	18.5	17.0
49	59	47	79	60	41	75	60	18.8	11.5	11.5	11.1	9.4	14.2	12.8	14.9	17.4	10.5	17.0	16.1	18.1	15.7
41	80	89	83	82	61	81	79	20.5	13.8	15.7	15.5	9.7	16.3	15.3	15.8	18.9	15.0	15.8	17.8	18.2	16.9
40	67	73	65	73	61	76	69	19.1	15.8	14.2	12.4	10.4	13.4	14.2	15.2	17.3	14.6	16.8	16.0	16.9	16.1
42	73	73	74	69	61	83	72	18.1	15.1	15.3	10.2	10.8	14.7	14.0	15.2	17.3	16.4	16.4	16.6	17.7	16.6
60	69	71	77	70	73	90	75	14.2	14.0	10.9	10.0	10.2	15.4	12.5	15.6	16.6	13.8	15.0	17.1	18.6	16.1
61	85	79	70	68	73	88	77	18.8	17.9	17.4	13.9	13.7	15.7	16.2	14.1	15.9	13.8	15.2	17.2	18.5	15.8
62	72	75	74	68	61	85	73	14.3	11.9	14.0	13.1	10.6	15.6	13.3	15.2	17.1	15.9	14.8	16.7	19.1	16.5
64	75	80	64	56	77	92	74	13.9	15.8	15.8	15.3	10.7	18.0	14.9	13.1	16.2	14.1	13.6	16.3	17.8	15.2
71–1	58	76	90	73	60	80	73	12.8	14.4	21.0	11.4	10.0	10.8	13.4	14.6	16.6	13.9	13.1	15.6	17.4	15.2
71–2	77	76	84	88	52	92	78	20.2	13.7	20.2	17.5	14.2	15.1	16.8	13.9	16.1	14.4	12.4	16.1	18.6	15.3
Mean	69	70	72	62	51	81	67	16.1	12.2	13.3	12.4	8.8	13.0	12.6	16.2	17.4	15.1	16.3	17.4	19.0	16.9

[1] 100 beets per 100 feet of row taken as base.

TABLE 5.—*Data on apparent purity coefficient and estimated sugar production, 1930–35, Scotts Bluff Field Station, Mitchell, Nebr.*

Rotation no.	Apparent purity coefficient							Gross sugar per acre							Indicated available sugar per acre						
	1930	1931	1932	1933	1934	1935	Mean	1930	1931	1932	1933	1934	1935	Mean	1930	1931	1932	1933	1934	1935	Mean
								Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
2	93.6	95.0	92.5	94.7	91.6	91.8	93.2	2,394	1,665	2,138	1,525	967	2,734	1,904	2,241	1,582	1,978	1,444	886	2,510	1,774
18	93.5	94.9	93.0	91.9	94.9	92.5	93.5	3,312	2,528	2,636	2,768	1,591	3,704	2,757	3,097	2,399	2,451	2,544	1,510	3,426	2,571
20	93.6	93.9	91.8	91.2	93.5	91.5	92.6	2,955	2,678	2,844	2,138	1,435	4,160	2,702	2,766	2,515	2,611	1,950	1,342	3,806	2,496
21	90.5	94.0	91.6	92.3	93.3	86.1	91.3	6,112	5,062	4,993	5,277	4,107	6,505	5,343	5,531	4,758	4,574	4,871	3,832	5,601	4,861
22	91.6	94.4	91.7	92.7	94.6	91.5	92.8	4,037	1,690	2,315	2,839	1,460	3,168	2,585	3,698	1,595	2,123	2,632	1,381	2,899	2,388
23	86.8	89.3	86.8	89.0	93.4	89.9	89.2	6,206	5,775	4,774	5,416	4,602	7,069	5,640	5,387	5,157	4,144	4,820	4,298	6,355	5,027
30	93.8	94.7	92.9	93.6	95.0	90.3	93.3	3,572	1,914	2,839	2,606	1,795	3,349	2,679	3,350	1,813	2,637	2,424	1,705	3,024	2,492
31	92.7	93.2	90.0	89.0	92.6	89.7	91.2	6,587	5,442	6,396	5,629	4,235	6,464	5,792	6,106	5,072	5,756	5,010	3,922	5,798	5,277
32	91.6	94.9	93.5	92.7	95.0	90.7	93.1	3,901	2,421	2,873	2,207	2,183	3,383	2,828	3,573	2,298	2,686	2,046	2,074	3,068	2,624
13	87.9	91.4	86.8	91.1	94.4	91.0	90.4	5,508	4,246	3,213	3,944	3,414	4,407	4,122	4,841	3,881	2,789	3,593	3,223	4,010	3,723
15	87.4	91.2	86.7	92.2	93.3	89.5	90.1	6,567	4,732	3,055	5,443	3,115	4,990	4,650	5,739	4,316	2,649	5,018	2,906	4,466	4,182
19	92.2	92.9	89.7	91.8	93.4	91.1	91.9	5,775	3,916	2,408	4,114	2,716	4,554	3,914	5,321	3,638	2,160	3,777	2,537	4,149	3,598
33	90.3	90.6	89.5	92.9	92.9	88.9	90.9	6,540	5,423	6,324	5,565	3,167	4,750	5,295	5,906	4,913	5,660	5,170	2,942	4,223	4,802
43	87.1	91.1	87.9	91.5	92.5	89.3	89.9	5,586	4,401	3,032	4,771	3,168	4,338	4,216	4,865	4,009	2,665	4,365	2,930	3,874	3,785
46–1	91.1	91.2	91.2	90.8	94.7	90.1	91.5	4,954	3,149	3,542	4,454	1,907	3,802	3,635	4,513	2,872	3,230	4,089	1,806	3,425	3,323
46–2	91.2	91.1	91.1	91.8	94.3	90.5	91.7	6,230	2,416	4,160	3,027	1,767	3,094	3,449	5,682	2,201	3,790	2,749	1,666	2,800	3,148
45–1	87.4	90.7	87.3	89.7	91.5	90.9	89.6	6,311	6,052	4,935	5,208	4,138	6,545	5,532	5,516	5,489	4,308	4,672	3,786	5,949	4,953
45–2	91.5	94.3	89.8	91.3	90.6	91.4	91.5	5,511	5,104	4,456	4,763	2,854	5,809	4,750	5,040	4,813	4,001	4,349	2,586	5,309	4,350
47	88.5	92.1	89.9	91.5	92.6	90.2	90.8	6,831	4,858	3,832	4,637	3,036	4,810	4,667	6,045	4,474	3,445	4,243	2,811	4,339	4,226
49	87.0	88.6	83.6	93.4	92.4	86.0	88.5	5,602	4,002	2,394	3,774	3,045	5,140	3,993	4,874	3,546	2,001	3,525	2,797	4,420	3,527
41	89.5	90.7	88.7	90.6	92.0	88.2	90.0	6,478	5,216	4,710	4,898	3,453	5,933	5,115	5,798	4,731	4,178	4,438	3,177	5,233	4,593
40	89.0	92.8	88.6	92.2	93.5	87.3	90.6	5,806	5,467	4,146	4,166	3,328	4,529	4,574	5,167	5,073	3,673	3,841	3,112	3,954	4,137
42	86.4	95.0	91.2	92.6	93.7	90.4	91.2	5,502	5,225	5,018	3,346	3,586	5,402	4,680	4,754	4,849	4,576	3,098	3,360	4,704	4,224
60	90.5	90.2	89.8	88.8	93.5	89.1	90.3	4,430	4,648	3,008	3,000	3,488	5,729	4,051	4,009	4,192	2,701	2,664	3,261	5,105	3,655
61	85.6	89.4	88.0	89.9	93.5	89.4	89.3	5,302	5,692	4,802	4,226	4,713	5,809	5,091	4,538	5,089	4,226	3,799	4,407	5,193	4,542
62	87.1	91.7	91.8	90.4	94.2	88.2	90.6	4,333	4,070	4,452	3,878	3,540	5,959	4,372	3,786	3,732	4,087	3,506	3,335	5,256	3,950
64	84.1	90.6	88.5	88.4	92.9	87.8	88.7	3,642	5,119	4,427	4,162	3,488	6,408	4,541	3,063	4,638	3,918	3,679	3,240	5,626	4,027
71–1	85.9	90.8	87.0	89.0	91.3	87.0	88.5	3,749	4,781	5,838	2,987	3,120	3,758	4,039	3,211	4,341	5,079	2,658	2,849	3,269	3,568
71–2	82.9	89.7	88.2	86.5	91.4	91.5	88.4	5,616	4,411	5,818	4,340	4,572	5,617	5,062	4,656	3,957	5,131	3,754	4,179	5,140	4,470
Mean	89.3	92.0	89.6	91.1	93.2	89.7	90.8	5,150	4,210	3,979	3,969	3,034	4,894	4,206	4,589	3,860	3,560	3,611	2,823	4,377	3,803

The rotations used permit a number of comparisons. It is possible to compare the general effect on yields of short, medium, and long cycles. Rotations with and without legumes may be contrasted. In a limited number of rotations special types of handling legume crops were employed. The data permit some comparisons of the effects of specific crops immediately preceding the beet crop. In some cases the same rotation scheme was used with and without manure. In the consideration of these major comparisons the data may be viewed from three points of view: (1) The effect upon yield of sugar beets; (2) the effect upon sucrose percentage; and (3) the effect upon acre yield of sugar (indicated available [6]). Indicated available sugar per acre reflects the value of the rotation as a whole for sugar beets, since it is influenced by the three factors, weight of beet, sucrose percentage, and apparent purity coefficient.

COMPARISON OF SHORT, MEDIUM, AND LONG ROTATIONS

This series of plots does not provide for a complete comparison of the effect of long and short rotations upon the production of sugar beets because of the fact that when there is a short interval between sugar-beet crops the intervening crop is usually a nonlegume and when the interval between sugar-beet crops is long a legume crop is introduced. This factor must be taken into consideration in a discussion of the effect of rotation length. Hence differences in yield of sugar beets in a short rotation, as compared with those in the long rotations, may indicate the effect of the legume crop rather than the effect of the time intervals.

The plot on which beets have been grown continuously since 1912 without any applications of manure has reached a low standard of production. During the last 6 years the average yield has been 5.2 tons of beets per acre, which is significantly lower than the mean of any of the other cropping systems.

The continuous beet plot has produced beets showing a very high sucrose percentage, which has consistently been slightly higher than that from any other plot. The present average is 18.3 percent. The continuous cropping of sugar beets, in which sugar beets showing a very high sucrose percentage are produced, indicates that this attribute cannot be increased with sufficient rapidity to compensate for decided losses in tonnage. The indicated available sugar produced on this continuously cropped plot shows an average of only 1,774 pounds per acre, which is approximately 750 pounds less than that from any other type of cropping tested. It is sufficiently low to show that continuous cropping is significantly poorer as a cropping practice than any other used with sugar beets at this station.

Table 2 shows the effect of 2- and 3-year rotations involving only cash crops to which no crop residues or manures were added. These systems are also unprofitable from the standpoint of sugar-beet production. Production has averaged only 2,514 pounds of indicated available sugar per acre produced from an average yield of 7.6 tons of sugar beets having an average sucrose percentage of 17.9. These plots have shown a marked uniformity in the tonnage of sugar beets produced per acre. The sucrose percentage has also been very similar. As compared one with another, they do not even approach a significant

[6] Acre yields of sugar are calculated as gross sugar, obtained by multiplying the weight of the beets by their sucrose percentage. Indicated available sugar is calculated by multiplying gross sugar by the apparent purity coefficient as a percentage factor.

difference in sucrose percentage or in tons per acre. From these rotations it is evident that high test for sucrose and high apparent purity coefficients of the sugar beet have not compensated for the low tonnages obtained. For profitable rotations of sugar beets the use of some method of maintaining tonnage seems very essential.

Probably many factors are involved in the poor yields secured from sugar beets in a rotation employing only cash crops; however, the main factor seems to be decrease in soil fertility. Observations of these plots over a period of years have shown that there may be a slight increase of the effect of sugar-beet diseases such as leaf spot and black root, but that these are not the major causes of low yield. There has been a heavy mortality of plants during the growing season on these plots, and the stand has been about 55 percent, but it is not known whether these death losses were due to black root diseases or to the lack of proper fertilizer elements in the soil.[7]

At harvesttime the beets from these plots are usually very small; in fact many of them are less than 1.5 inches in diameter and are not salable because of lack of size. The top growth on these beets also is always small, and they show an indication of maturity very early in the season.

In one of the 4-year rotations (46) two crops of sugar beets are grown with an oat crop after the first crop of beets, and a potato crop after the second crop of beets. The sucrose percentages of these two crops of beets averaged the same (17.9), and there was no important difference in the yield of tons per acre or indicated available sugar. In 3 of the past 6 years rotation 46–1 has yielded a higher tonnage than 46–2 and in 3 years a lower tonnage. The production of indicated available sugar in rotation 46 has been significantly better than the 2- and 3-year rotations involving only cash crops or continuous cropping. However, rotation 46 was begun in 1926, while the other rotations were begun in 1912, which would leave some room for doubt whether this difference of indicated available sugar per acre was due to any other factor than that of plot location and the period involved.

All these rotations consisting exclusively of cash crops are unprofitable. None of them are long, but there are probably sufficient differences in rotation length among them so that if increasing the interval between beet crops increased sugar-beet yield, such should have been shown.

Consistently high sucrose percentages were obtained from beets in all rotations in which no legume crop is included or manure used (nos. 18, 20, 22, 30, 32, and 46). The sucrose percentage of these rotations varies from a high of 18.2 to a low of 17.6. The requirement for significance is ± 1.02, and the small differences existing may be assigned to chance variation.

COMPARISON OF ROTATIONS WITH AND WITHOUT LEGUME CROPS

The rotations make possible a comparison of the two legume crops, sweetclover and alfalfa. The sweetclover crop has been handled by different methods, being fall-plowed, spring-plowed, and pastured, as well as removed as a hay crop. The alfalfa has been planted in April, either with or without a nurse crop of small grain, and the hay

[7] G. H. Coons, principal pathologist, Division of Sugar Plant Investigations, examined these plots on Sept. 2, 1936. He found a few cases of fusarium yellows (*Fusarium conglutinans betae*) on rotations 2 and 20 and practically no indications of disease on other plots.

removed three times a year for a period of 2 or 3 years. In all instances except in rotation 42 the alfalfa has been allowed to make some spring growth and has then been plowed under for potatoes. The plowing has been done the latter part of May or the first few days in June.

The results of the 2-year rotations of sweetclover and sugar beets (nos. 13, 15, and 19) have not shown significant differences in indicated available sugar per acre, but in rotation 15 there is significant increase in tons of beets per acre over the yield in rotation 19, and the sucrose percentage is slightly lower. The indicated available sugar in rotation 15 approaches significance when compared with that of rotation 19. These three rotations give a measure of the efficiency of sweetclover in the rotation in which it is plowed under in the fall of the year in which it is planted. In the first place, all three rotations gave results indicating a significant increase in acre yield of sugar over the previously discussed cash crop, nonlegume rotations. During the past 6 years the average increase in rotations 13, 15, and 19 over nos. 18, 20, 22, 30, and 32, which are similar except that they do not include sweetclover, has been 1,320 pounds of indicated available sugar per acre, an increase of slightly over 50 percent. This increase in indicated available sugar has been largely due to an increase in tonnage, as there is only a slight decrease in sucrose percentage. It seems proper to call special attention to the value of the sweetclover with a grain nurse crop where no other legume or manure is used in the growing of sugar beets. In the second comparison the results of these rotations indicate that when the sweetclover hay is removed, the least sugar per acre, the least tonnage, and beets of the highest sucrose percentage are produced; when the crop is fall-plowed, intermediate yields are produced; and when the sweetclover is pastured with sheep apparently the sugar-beet crop is most benefited.

The beets from rotation 33 are significantly higher in indicated available sugar per acre than those from rotations 13 or 19 and approach significance over those in rotation 15, but are not significantly higher in sucrose percentage than those from either of these rotations. The gain is made by a significant difference in tonnage over rotations 13 and 19; the beets from rotation 15 have the lowest sucrose percentage. The gain of the beets in rotation 33 over those in rotations 13, 15, and 19 may be due to the better physical condition of the seedbed for the sugar beets when following potatoes. The fall-plowing of the sweetclover has been done late in the fall, and there has always been some damage to the beet crops on these rotations because of growth from the plowed-under sweetclover crowns.

In the 2-year rotations the sweetclover was fall-plowed, while in the 4-year rotations the sweetclover was spring-plowed in all instances. This makes it impossible to make any direct comparisons as to length of rotation. In spring-plowing sweetclover for sugar beets there is very little growth, but the later planting date used for potatoes allows for more growth of the sweetclover, which is usually 2 feet high when plowed. As important as the greater growth, is perhaps the more complete killing of the sweetclover by the later plowing. In all instances where sweetclover is followed by sugar beets on these plots there has been some injury from the sweetclover persisting as a weed. Where the sweetclover is pastured the second year after planting there is much less of this type of injury.

In rotation 43, where sweetclover is fall-plowed after being pastured by sheep, the yield is not so satisfactory as in rotation 47, where the sweetclover was not pastured. Pasturing seemed to have slightly depressed the sucrose percentage recorded for rotation 43 but did not increase the tonnage. These 4-year sweetclover rotations show some differences in sucrose percentages. Beets from rotations 40, 43, and 49 are significantly lower in sucrose percentage than those from rotation 45–2, which tested high the second time they occurred in the rotation. With the exception of rotations 45–2 and 49, the differences in sucrose percentages are not significant. No. 49 produced the lowest yield and beets of the lowest sucrose percentage; there is no apparent explanation unless the bean crop has some bad effect. The most productive rotation in which sweetclover is used is no. 45–1; no. 45–2 produces beets that rank third in value in indicated available sugar. It shows the high value of the 4-year rotation, 2 years of beets and 2 years of sweetclover; however, nos. 45–1 and 45–2 are an older rotation, started in 1920, while the other sweetclover rotations were begun in 1926. Rotation 41 is similar to rotation 45 in the way the sweetclover is handled, the former having a crop of potatoes grown in place of one of the beet crops.

The return from the beet crop on rotation 43 should apparently be similar to that from rotation 15 but does not equal no. 15 in any factor of yield. No explanation is apparent.

Pasturing the first year of sweetclover gives no advantage, but benefits are derived when the sweetclover is pastured the second year. The sucrose content is satisfactory where sweetclover is handled in this manner. One noticeable fact is that no crop of sugar beets directly following pasturing of sweetclover exceeds the 16.7 percent sucrose content of rotation 15, which is only fall pastured.

Two years of alfalfa for hay does not give so good results as pasturing the sweetclover, but rotations 40 and 42 are satisfactory. As a whole the alfalfa rotations have not produced so high amounts of indicated available sugar per acre as the sweetclover rotations; however, where the sweetclover is removed from the land in any manner other than pasturing, the yields of beets have not exceeded those in the alfalfa rotations. It must be kept in mind that the alfalfa rotations were begun in 1912 or 1920, while most of the sweetclover rotations were started in 1926. There are four rotations of 6 or 7 years in which sugar beets are grown with alfalfa crops, without benefit of manure. In two of these rotations (60 and 62) the same sucrose percentages and about the same indicated available sugar per acre were obtained as from rotations 40 and 42, while rotations 64 and 71 are significantly lower in sucrose. The reason the sucrose percentage of beets from rotation 64 is lower than that of beets from rotation 60 and the tonnage of rotation 60 lower than that of rotation 64 may be due to some effect arising from the place of the oats and potato crops in the rotation. There may be some condition of the soil that causes sugar beets after oats to be slightly higher in sucrose percentage and lower in tonnage than is the case when beets are grown after potatoes. Further evidence of such an effect appears in the results obtained in some of the sweetclover rotations and also in comparing rotations 46–1 and 46–2; however, the differences are not great enough to be significant.

The variations in the apparent purity coefficients have generally followed the variations in sucrose percentage. The continuous crop-

ping and the 2- and 3-year cash-crop rotations are significantly higher than the other rotations where legumes are included. The differences in purity have not been sufficient to have any appreciable effect on the indicated available sugar per acre.

In summarizing the effects of legumes on crop rotation at this station, it is found that use of legume crops in the rotation has produced consistent and profitable increases of the sugar-beet crop. The results from including fall-plowed sweetclover in the rotation indicate that significant gains are obtained over the results from rotations in which legumes are not used. Alfalfa in the rotation for 3 years has not produced such definite effects as some of the sweetclover rotations. It is to be noted that in all of these types of rotation—continuous cropping, cash crops, or rotations with legume crops—only one outstanding consideration apparently has had a controlling influence in the choice of a rotation for sugar-beet growing; namely, the rotation that produces the greatest increase in tons per acre is the one that produces the greatest indicated available sugar per acre. Gains in sucrose percentage and apparent purity have been associated with low tonnages, and these gains have not given sufficient increase in indicated available sugar per acre to compensate for low yield of beets. In these tests, the inclusion of legume crops in the rotations did not depress the sucrose percentage and apparent purity enough to make it desirable to exclude legumes from the rotations in which no manures are applied.

EFFECT OF THE USE OF MANURE WITH CROP ROTATIONS

When manure is applied in the crop rotation, distinct variations in sucrose percentage, apparent purity, and yields occurred. The general effect of manure is to increase the tonnage and indicated available sugar per acre and slightly decrease the sucrose percentage and apparent purity. None of the rotations here studied received large amounts of manure per acre; therefore no great depression in sucrose percentage would be expected. The rate of manuring within the rotation cycle has been 12 tons per acre in all of the plots summarized in table 3. In rotations 21 and 23, manure is applied in alternate years; in rotation 31, the application is made each third year; in rotation 61, the application is made once in 6 years, and in rotation 71–2, the manure was applied each seventh year. In all instances the beets received the direct benefit of the application except in rotation 21, where the manure was applied to the potato crop.

The rotations in table 3 permit of four direct comparisons of rotations with and without manure. Rotations 71–1 and 71–2 are the unmanured and manured beet crops in the same rotation. The beet crop in 71–1 may have benefited slightly by the residual effect of the manure applied to the land 6 years previously, but the indications are that the value was not more than 0.9 ton per acre, as that is the gain of rotation 71–1 over rotation 60.

Rotations 20 and 22 do not indicate that oats or potatoes as preceding crops are a distinct factor influencing yield of sugar beets. The slightly higher acre yield of indicated available sugar in rotation 23 than is found for rotation 21 may be due to the direct application of manure to the beet crop in the case of the former rotation.

Rotation 31 (sugar beets (manured), potatoes, and oats) gave the highest yield of indicated available sugar per acre and also showed the highest sucrose percentage of any in the manured series of rotations.

Beets in rotations 21, 23, and 31 show higher sucrose percentages than those in rotations 61 and 71–2. In the latter two rotations the 3 years of alfalfa may have had some effect upon the sucrose percentage. This should be especially true of rotation 60.

The five rotations receiving manure, as shown in table 3, show a gain of 6.8 tons of beets or 1,915 pounds of indicated available sugar per acre for the use of the manure and a decrease of only 0.5 percent in sucrose percentage. The rate of manuring, being only 12 tons per acre in a rotation cycle, can be considered as 12 tons of manure per acre direct to the sugar-beet crop but is less than that amount when allowance is made for residual effects. The gain is sufficiently great to show a good profit for the use of the manure considering the gain in the beet crop only, as the value for the manure must have been at least 0.57 ton of beets for each ton of manure used.

CONCLUSIONS

While the omission of legumes and manure in the rotations produced sugar beets with a high percentage of sucrose, the acre yields of sugar beets were so low that it seems necessary to use manure or legumes to increase the yield if a profitable sugar-beet crop is to be produced.

The high-yielding individual rotations, based upon indicated available sugar per acre, in the order given are nos. 31, 23, 45–1, 21, 33, and 41. In tons of beets produced per acre there was no significant difference in this group, and the same was true in yield of gross and indicated available sugar. Beets from rotation 23 were significantly lower than those from rotation 31 in sucrose percentage and apparent purity coefficient. Four of these rotations produced beets with a sucrose percentage of 16.9 or higher. In none of the rotations showing highest rank in yield of indicated available sugar were both manure and legume crops used. Three of the high-yielding rotations included sweetclover, and in two of them matured sweetclover was pastured. There is no very logical explanation of why rotation 33 should be in this high-yielding group. However, rotations 61 and 71–2 have yields not significantly lower in indicated available sugar than any of the above-named rotations except no. 31, and include the use of both manure and legumes; therefore, it cannot be assumed that the application of moderate quantities of manure in connection with rotations in which alfalfa is used constitutes an unfavorable practice for sugar beets. The two rotations mentioned are well suited to the western Nebraska beet-growing area and are of superior value.

It is noticeable that in the six rotations producing the highest indicated available sugar per acre there were two 2-year rotations, two 3-year rotations, and two 4-year rotations. These rotations indicate that while the use of manures and legumes may have a slightly depressing influence on the percentage of sucrose in the beet, their rational use is necessary for the production of satisfactory crops of sugar beets.

These rotations do not indicate that corn, spring wheat, oats, or potatoes have sufficient influence upon the percentage of sucrose in beets or the indicated available sugar produced per acre to cause the

selection of any one of these crops to precede sugar beets. On the basis of present knowledge, the selection should be made upon the value of the crop used and not upon its probable effect on sugar-beet quality.

Factors that increase tonnage yields of beets usually decrease the percentage of sucrose. This reduction, however, is not in the same order in all combinations of legumes and manures, and there is still much to be accomplished in increasing the tonnage yield of beets and maintaining at the same time an acceptable sucrose percentage in the beet.

The average sucrose percentage of beets for rotations without manure or legume crops is 17.9, which is 0.4 lower than that obtained from the continuously cropped beets. Short cropping with sweetclover reduces the sucrose content of beets approximately 0.6 percent below that shown for cash crops. The 4-year rotations, which include 2 years of alfalfa or 2 years of sweetclover, reduce the sucrose percentage of beets to 16.5, a numerical reduction of 1.4 in sucrose percentage below the average for cash-crop rotations. The longer rotations, alfalfa without manure, produce beets with a sucrose percentage of 15.9, representing an analysis of 2.0 lower than that from the cash-crop rotations. It is noticeable that manure alone in small quantities (rotations 21, 23, and 31) produced beets testing 17 percent in sucrose, or only 0.9 lower than the cash-crop rotation average. Manure and legumes in rotations 61 and 71–2 produce beets testing 15.6 percent, which is lower in sucrose percentage by 2.3 than the average for the cash-crop rotations. There seems to be a factor in the combination of legumes and manure that should be studied further for its effect upon sucrose percentage of sugar beets; however, legumes in long rotations may have more influence upon the sucrose percentage than the manure has.

From the trends of the beet yields in these plots it would seem unlikely that a grower should choose a long rotation solely on the basis of returns from the sugar-beet crop, but rather that he should largely consider the returns obtained from the crops other than sugar beets. It is recognized that long or moderately long rotations have a decided influence on nematode infestation and on the prevalence of leaf spot. The use of manure in combination with the legume crops in the longer rotation produced some very high tonnages with fairly high acre yields of sugar, but the general effect on quality should not be disregarded.

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U. S. GOVERNMENT PRINTING OFFICE: 1937

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